PB 189 360

REGULATIONS, STANDARDS, AND GUIDES FOR MICROWAVES, ULTRAVIOLET RADIATION, AND RADIATION FROM LASERS AND TELEVISION RECEIVERS - AN ANNOTATED BIBLIOGRAPHY

Lloyd R. Setter, et al

Bureau of Radiological Health
Rockville, Maryland

April 1969

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ENVIRONMENTAL HEALTH SERIES

Radiological Health

REGULATIONS, STANDARDS, AND GUIDES FOR MICROWAVES, ULTRAVIOLET RADIATION, AND RADIATION FROM LASERS AND TELEVISION RECEIVERS—AN ANNOTATED BIBLIOGRAPHY

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

Consumer Protection and Environmental Health Service

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The National Center for Radiological Health was reorganized December 1968. It is now the Bureau of Radiological Health, with Dr. Raymond T. Moore, as the Acting Director.

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FOREWORD

The 1967 Congressional Hearings on the control of radiation from electronic products have made clear the need to organize the information on existing regulations, standards, and guides developed by Federal, State, and municipal governments, military organizations and nongovernmental organizations. This annotated bibliography was prepared in a form which aids in the comparison of existing or proposed regulations, standards, and guides for further evaluation with respect to adequacy of health protection and control, with consideration given to the economic and technologic factors.

The bibliography was prepared by the Standards Services Branch, Office of Criteria and Standards, in cooperation with the Electronics Products Radiation Laboratory (now the Division of Electronic Products), Bureau of Radiological Health. Copies are available for distribution to organizations and individuals who need this information. The project is a part of the Bureau of Radiological Health's program to assist organizations and individuals who are responsible for protecting the public against the harmful effects of excessive radiation.

Raymond T. Moore, M.D.
Acting Bureau Director
Bureau of Radiological Health

PREFACE

In preparing this annotated bibliography many individuals provided information and reviewed draft copies. Appreciation is expressed to the Division of Medical Radiation Exposure and the Division of Electronic Products for making available their index files and standards documents.

We wish to thank all of the reviewers of the bibliography. Extensive comments and/or suggested documents not in the preliminary draft were received from:

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We particularly appreciate having Dr. Garlan's permission to reproduce two tables that appear in the bibliography which were prepared by the Federal Communications Commission.

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ABSTRACT

This report is an annotated bibliography of guidelines, standards, and regulations pertaining to public health protection against electromagnetic radiation from television receivers, lasers, ultraviolet radiation, and microwaves. Each category of radiation is treated in a separate section.

Since the terminology for regulations, standards, and guides is not uniform among Federal, State governments, municipal governments, military organizations, and nongovernmental organizations, the annotated documents are designated as Class A (established or adopted by a governmental body acting under the authority of an act, law, or statute), Class B (adopted by consensus of a committee(s) or commission(s) of technical competence in standards-setting organizations), or Class C (not adopted by a standards-setting organization, but contains information pertinent to the preparation of suitable standards or regulations).

The annotations include identification of the document, type of standard, intended complier, intended benefitter, limits and specifications, and general guidance.

Representative products and manufacturers are named for identification only, and listing does not imply endorsement by the Public Health Service and the U.S. Department of Health, Education, and Welfare.

THE AUTHORS

Dr. Lloyd R. Setter and Mr. David R. Snavely are staff members and Mr. Rodman F. Van Wye was a former staff member of the Standards Services Branch, Office of Criteria and Standards; and Mr.Duane L. Solem is a staff member of the Division of Electronic Products; all of the Bureau of Radiological Health, Rockville, Maryland 20852.

REGULATIONS, STANDARDS, AND GUIDES FOR MICROWAVES, ULTRAVIOLET RADIATION, AND RADIATION FROM LASERS AND TELEVISION RECEIVERS -- AN ANNOTATED BIBLIOGRAPHY

INTRODUCTION

This annotated bibliography summarizes the information contained in regulations, standards, and guides in the United States pertaining to x rays from television receivers, lasers, ultraviolet radiation, and microwaves. Selected documents published in foreign countries and by international organizations were also abstracted. Since few standards for protection against ultraviolet radiation have been promulgated, several excellent references on basic information are given in Section I. Section I contains a summary of radiations in the electromagnetic spectrum. Some guides annotated in the laser section are authored by one or two individuals. These were selected from the many available to represent the current trends in laser safety guidance. The information on biological effects has been restricted to that given in the standards documents and the background information in Section I.

The general format for annotation is:

1. Subject of document or annotated part of document.
2. Originating organization or individuals.
3. Publication identification.
4. Type of "standard."
5. Intended compliers.
6. Intended benefitters.
7. Limits and specifications.

8. General guidance.

The type of standard is classified as either Class A, Class B, or Class C.

Class A - A standard, code, criterion, specification, rule, performance requirement, procedure, or method established or adopted by a governmental body acting under the authority of an act, law, or statute.

Class B - A standard, code, criterion, specification, rule, performance requirement, procedure, or method prepared and/or adopted by consensus of a committee(s) or commission(s) of technical competence in standards-setting organizations. These standards may be incorporated in whole or in part into a regulation. They may have restricted application depending upon the choice or obligation of individuals or users of the standard.

Class C - A guide, standard, code, criterion, specification, rule, performance requirement, procedure or method which has not yet been adopted by a standards-setting organization but contains information pertinent to the preparation of suitable standards or regulations.

Under TYPE in the annotation are entered the class, the name of the originator and a subclass, such as regulation, standard, code and specification, as defined by the originator.

The INTENDED COMPLIERS are the individuals or organizations for whom the standard was prepared as stated directly or implied in the document. The INTENDED BENEFITTERS are the individuals who are supposed to receive protection.

LIMITS AND SPECIFICATIONS include exposure limits, technical specifications, operating specifications, and other information usually expressed quantitatively. Not all documents include all of these subcategories of limits and specifications. Quantities specified as exposure limits in the annotations clearly have biological significance. In other cases, the kinds and quantities of radiation that may exist in controlled environments are given. A large number

of the regulations of the Federal Communications Commission (FCC) are in this category. These regulations were written as standards for maintaining noninterfering power levels of radio transmitters. The FCC regulations do not necessarily specify safe levels of radiations.

GENERAL GUIDANCE includes a variety of information that is important for health protection. The particular kind varies with the subject of the document.

DEFINITIONS AND EQUIVALENTS

SYMBOLS

AM	Amplitude Modulation
Å	Angstrom
g cal	Gram calorie
eV	Electron volt
dB	Decibel
FM	Frequency Modulation
F	Frequency
Hz	Hertz
J	Joule
m	Meter
mR	Milliroentgen
RF	Radio Frequency
s	Second
V	Volt
W	Watt

PREFIXES

Multiples and submultiples	Prefixes	Symbols
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

EQUIVALENTS

Unit	Equivalent
Ångstrom	0.1 millimicron; 10^{-10} meters; 0.1 nanometers
Electron Volt	10^{-12} erg
Hertz	1 cycle per second
Joule	10^{7} erg
Watt	1 joule/s

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SECTION I THE ELECTROMAGNETIC SPECTRUM

The majority of regulations, standards, and guides pertain to protection against radiations in specific ranges in the electromagnetic spectrum, such as gamma, x, ultraviolet, visible, infrared, and microwave radiations. Some guides and excellent background material pertain to several portions of the spectrum. A list of reference books and documents for orientation to the various kinds of radiations in the whole electromagnetic spectrum follows figure 1.

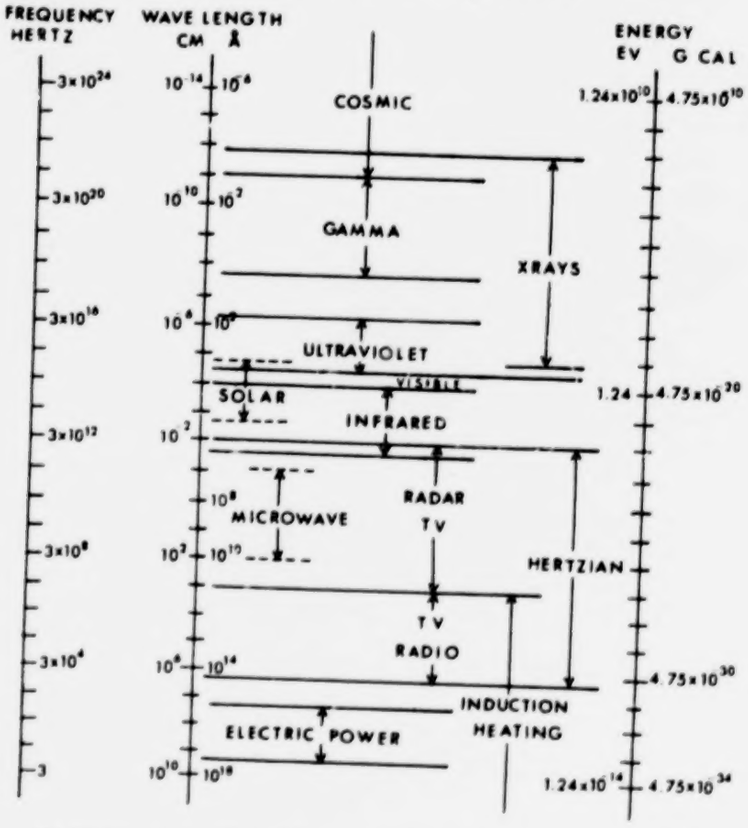

Figure 1. The Electromagnetic Spectrum[1]

[1]Reproduced from article by B. G. Ferris with permission of author and publisher.

By recommending the following references, we do not imply that other references are not also excellent.

BAETJER, A. M. Preventive Medicine and Public Health, P. E. Sartwell, Editor. Chapter 25 on Radiation, 733-757. Appleton-Century-Crofts, New York, 9th Ed. (1965).

FERRIS, B. G. Environmental hazards, electromagnetic radiation. New Engl J of Med 275:1100-1105 (November 17, 1966).

MUMFORD, W. W. Some technical aspects of microwave radiation hazards. Proc I.R.E. (Inst Radio Engrs) 49:427-447 (February 1961).

FANNEY, J. H., JR. and C. H. POWELL. Field measurement of ultraviolet, infrared, and microwave energies. Am Ind Hyg Assoc J 28:335-342 (July-August 1967).

KOLLER, L. R. Ultraviolet Radiation. John Wiley and Sons, New York (1965).

HOLLAENDER, A., Editor. Radiation Biology, Volume II: Ultraviolet and Related Radiations. McGraw-Hill Book Company, New York (1955).

LIGHT, S., Editor. Therapeutic Electricity and Ultraviolet Radiation. Waverly Press, Baltimore, 2nd Ed. (1967).

The following standards contain definitions that apply to more than one category of protection.

Definitions of Electrical Terms
Electron Devices, Group 70
United States of America Standards Institute
USASI - C42.70 - 1956

Definitions of Electrical Terms
Electrobiology Including Electro Therapeutics, Group 80
United States of America Standards Institute
USASI - C42.80 - 1957 -- IEC 50(70)

Although this bibliography is not intended to include an extensive list of publications dealing with basic research on biological effects of laser beams, the following references to works by investigators of laser eye damage are included for background purposes:

ZWENG, H. C. R. C. ROSAN, R. R. PEABODY, R. M. SHUMAN, A. VASSILIADIS, and R. C. HONEY. Experimental Q-switched ruby retinal damage. Arch Ophthalmol (Chicago) 78:634-640 (November 1967).

HAM, WILLIAM T., JR., R. C. WILLIAMS, H. A. MUELLER, DUPONT GUERRY, III, A. M. CLARKE, and W. J. GEERAETS. Effects of laser radiation on the mammalian eye. Trans N Y Acad Sci Series II 28:4:517-526 (February 1966).

SECTION II. X RAYS FROM TELEVISION RECEIVERS

Domestic Television Receivers

Council of State Governments

The Council of State Governments, 1313 East Sixtieth Street, Chicago, Ill., 60637, Page 7, Section B.6, October 1964.

Type: Class B. Suggested State regulations.

Intended Compliers: Domestic television receiver manufacturers.

Intended Benefitters: General public.

Limits and Specifications

Domestic television receivers are exempt from licensing and registration providing the dose rate at 5 cm from any outer surface is less than 0.5 mrem/hour.

General Guidance

None.

X-Ray Protection Standards for Home Television Receivers

National Council on Radiation Protection and Measurements (NCRP)

Interim Statement of the NCRP, 4201 Connecticut Avenue, NW., Suite 402, Washington, D.C. 20008, Approved February 23, 1968.

Type: Class B. Recommendation of the NCRP

Intended Compliers: Manufacturers of home television receivers.

Intended Benefitters: General public.

Limits and Specifications

The NCRP 1959 recommendation "that the exposure dose rate at any readily accessible point 5 cm from the surface of any home television receiver shall not exceed 0.5 mR/hr under normal operating conditions" is reaffirmed. It is stated that the basic intent of the NCRP recommendation will be met if the exposure rate, averaged over an area of 10 cm^2, does not exceed the stated 0.5 mR in an hour at any external location 5 cm from the surface of the television receiver cabinet.

General Guidance

The NCRP intends to give further study to the broad problems resulting from the use of radiation-emitting devices by the general public through its recently established Scientific Committee on Radiation Exposure from Consumer Products. This committee will consider in detail the problem of television receivers. It is the judgment of the NCRP that the use of television receivers in the home should not contribute to the annual genetically significant dose of the population in excess of about 5 percent of the average dose from natural background radiation. The phrase "under normal operating conditions," as used in the 1959 statement, means that the set and the potentially radioactive components shall operate within the specifications defined in accordance with accepted industry practices.

SECTION II. X RAYS FROM TELEVISION RECEIVERS

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General Guidance

None.

X-Ray Protection Standards for Home Television Receivers

National Council on Radiation Protection and Measurements (NCRP)

Interim Statement of the NCRP, 4201 Connecticut Avenue, NW., Suite 402, Washington, D.C. 20008, Approved February 23, 1968.

X-Radiation Test

Underwriters' Laboratories, Inc. (UL)
Standards for Safety, Radio and Television Receiving Appliances, UL492, 11th Ed., Paragraphs 301 and 302, November 1964 (Paragraphs 301 and 302 revised April 1968).

Type: Class B. Standard of the Underwriters' Laboratories, Inc.

Intended Compliers: Manufacturers whose products bear the UL seal of approval.

Intended Benefitters: General public.

Limits and Specifications

"X-radiation test - The X-radiation of a television receiving appliance shall not exceed 0.5 milliroentgens per hour at any point located 5 centimeters from the outer surface of the overall enclosure of the appliances.

"The appliance is to be complete, except mechanical parts subject to removal during user servicing may be omitted if they are (1) not necessary for the functioning of the appliance, (2) not exposed to view during normal operation, and (3) not captivated. Adjustable controls are to be adjusted within the range of normal operation of the appliance so as to produce the maximum X-radiation."

The word "captivated" is used to convey the concept that a part is one which can not be discarded or thrown away inadvertently. Captivation can be accomplished by a hinge, a short length of flexible wire or chain, or equivalent construction. To discard a captivated part requires a deliberate act involving undue force, or the use of tools other than a flat-bladed screwdriver or pliers.

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General Guidance

None.

Recommended Practice for Measurement of X-radiation from Display Cathode-Ray Tubes

Joint Electronic Device Engineering Council (JEDEC) Electron Tube Council

JEDEC Publication No. 64, Electronic Industries Association, September 1967.

Type: Class B. Recommended practices for measurement.

Intended Compliers: Manufacturers of cathode-ray tubes.

Intended Benefitters: Manufacturers of cathode-ray tubes and the groups responsible for compliance.

Limits and Specifications

Recommendations made include the use of an ionization chamber (15 cm in diameter by 10 cm in length) and electrometer combination which shall be calibrated by exposure to a known filtered x-ray field generated at 25 to 35 kV, a stopwatch for measuring exposure time with an accuracy of at least ± 1.0 percent, a meter for measurement of the anode (cathode-ray tube) voltage during test with an accuracy of at least ± 0.5 percent, and a meter for measurement of the anode current during test with an accuracy of at least ± 2.0 percent. The tube under test shall be operated at the required anode voltage and current which shall not vary or drift more than ± 0.5 percent during the entire test period, and radiation measurements should be made at the center of the tube face with 2.5 cm between the tube face and the circular face of the ion chamber and at other positions described in the document.

General Guidance

The testing instrument, method of calibration, test conditions, and the procedures to be used in making the measurement are described.

Recommended Practice for Measurement of X-Radiation from Receiving Tubes

Joint Electronic Device Engineering Council (JEDEC), Electron Tube Council

JEDEC Publication No. 67, Electronic Industries Association, February 1968.

Type: Class B. Recommended practices for measurement.

Intended Compliers: Manufacturers of high-voltage receiving tubes (rectifiers and regulators).

Intended Benefitters: Manufacturers of high-voltage receiving tubes and agencies checking compliance.

Limits and Specifications

1. A survey meter (Victoreen Model 440 RF, or equivalent) is intended as the principal measuring instrument. Other detectors of low energy x-radiation, such as Geiger-Mueller counters, proportional counters, scintillation counters, or solid-state counters, may be used provided the calibration is known over the energy ranges being measured.

2. Ionization chamber - 4.5-inch (11.43 cm) diameter and 4-inch (10.16 cm) length cylinder ionization chamber (Victoreen 208A, or equivalent), used in combination with a Minometer*. This chamber is meant to be a secondary mea-

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*Registered tradename.

suring instrument, but can be utilized as a reference standard.

3. Minometer* - A device for charging the ionization chamber and reading the residual charge after exposure (Victoreen II Model 687C, or equivalent).

4. Timer - A stopwatch or equivalent device with an accuracy of at least ± 1.0 percent.

5. High-voltage meter - accuracy of at least ± 0.5 percent.

6. Current meter - accuracy of at least ± 2.0 percent.

7. Ionization chamber support - constructed of wood or plastic.

8. Instrument calibration procedures are stipulated.

9. Calibration of survey meter and/or ionization chamber and Minometer* combination - exposure to an x-ray field of such an energy that the half-value-layer of aluminum is 0.9 mm (effective energy of 21 keV).

10. Test conditions - regular tube under test shall be operated at the maximum rated high d.c. plate voltage and current which shall not vary more than ± 0.5 percent during the entire test period; rectifier tube shall be tested under d.c. conditions with the d.c. potential, corresponding to the maximum rated peak inverse voltage (total d.c. and peak), applied to the cathode or filament. Voltage shall not vary more than 0.5 percent during the entire test period.

11. Procedures - The distance from the surface of the tube under test to the center of the chamber (ionization) shall be 6 inches. Survey meter - radiation measurements shall be made and recorded at the location of maximum stable intensity; ionization chamber - three radiation measurements shall be made at the location of maximum intensity and the average reading recorded (no individual readings shall differ by more than 10 percent from the average) for regulator tubes and the highest reading for rectifier tubes.

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*Registered tradename.

General Guidance

Recommended are specifications and general guidance on the monitoring equipment, method of calibration, test conditions, procedures for making measurements, and the information that should be recorded in making the measurements.

Normal Operating Conditions and Ionizing Radiation

(Those pertaining to television sets)

International Electrotechnical Commission (IEC) and International Commission on Rules for the Approval of Electrical Equipment (CEE)

Safety Requirements for Mains Operated Electronic and Related Equipment for Domestic and Similar General Use, IEC Publication 65, 2d Ed., and CEE Specifications, Publication 1, 3rd Ed., Sections 4.2 and 6, pages 17 and 27, 1965.

Type: Class B. International safety requirement recommendations.

Intended Compliers: Manufacturers of apparatus connected to the mains (electric circuit) and intended for domestic and similar general indoor use.

Intended Benefitters: General public.

Limits and Specifications

The recommendations state that normal operating conditions are considered to consist of the most unfavorable combination of the following conditions (only those conditions which would effect the measurement of x-radiation from television sets are given below):

1. Any position of normal use of the apparatus, normal ventilation not being impeded. This will be obtained by positioning the apparatus on a horizontal support having dimensions not smaller than that of the apparatus base, leaving a free space of not less than 5 cm depth behind the apparatus.

2. A supply voltage of 0.9 times or 1.1 times any rated supply voltage for which the apparatus is set. Any rated frequency of the supply voltage. For a.c./d.c. apparatus, a.c. or d.c. supply.

3. Any position of controls which are accessible to the user for adjustment by hand, except voltage adaptors. Any remote control device, connected or not.

The apparatus shall be constructed to provide personnel protection against ionizing radiation. Compliance is checked by measuring the amount of radiation. The dose rate at any readily accessible point 5 cm from the outer surface shall not exceed 0.5 mR/hour under normal operating conditions. The amount of radiation is determined by a monitor of the ionization chamber type with an effective area between 50 and 100 cm^2 and with an effective volume between 500 and 1,000 cm^3. (This last sentence was added in the November 1967 draft revision of section 6 of the International Electrotechnical Commission Publication 65 "Safety Requirements for Mains Operated Electronic and Related Equipment for Domestic and Similar General Use." This became effective in April 1968.)

General Guidance

None.

Television Sets

International Commission on Radiological Protection (ICRP)

Report of Committee III, ICRP on Protection Against X-Rays up to Energies of 3 MeV and Beta- and Gamma-Rays from Sealed Sources, ICRP Publication 3, page 14, Pergamon Press, 1960.

Type: Class B. Recommendations of the ICRP.

Intended Compliers: Manufacturers of television sets and users.

Intended Benefitters: General public and persons using television sets or projection equipment in their work.

Limits and Specifications

"The dose-rate at any readily accessible point 5 cm from the surface of any set used in the home or place where the public is likely to be in close proximity shall not exceed 0.5 mR/hr under normal operating conditions."

General Guidance

All other television equipment, such as those used for projection purposes or in closed-circuit applications in which electrons are accelerated to an energy in excess of 5 keV, shall be so constructed, installed, and operated, as to provide adequate protection and whenever practicable shall be shielded and provided with interlocks so as to ensure that places where they are used can be regarded as being outside "controlled areas" thus avoiding the need for monitoring procedures and special medical examinations. Such equipment includes electron microscopes, cathode-ray tubes, high-voltage electronic rectifiers, transmitting valves, television and image tubes.

Particular attention is drawn to the hazards which may arise during the manufacture, testing, and repair of all such equipment.

Skin, Paragraph 28 under Critical Organs and Tissues

International Commission on Radiological Protection (ICRP)
Recommendations of the ICRP, ICRP Publication 9, page 6,
Pergamon Press, 1966.

Type: Class B. ICRP recommended radiation protection guides.

Intended Compliers: Member countries.

Intended Benefitters: All individuals and populations.

Limits and Specifications

For external exposure of the skin it is recommended that the dose be averaged over an area of 1 cm^2 in the region receiving the highest dose. However, with very narrow beams of extremely high intensity, such as those used for x-ray analysis, the value of such an average dose may be misleading and protective measures have to be based on qualitative considerations.

General Guidance

None.

Domestic Television Receivers

National Committee on Radiation Protection and Measurements
Suggested Radiation Protection Regulations, Draft of Revision
to Appendix B, National Bureau of Standards Handbook 61,
Health Physics Journal, 5:3 (April 1961).

Type: Class C. Draft of a Model Regulatory Code.

Intended Compliers: Domestic television receiver manufacturers.

Intended Benefitters: General public.

Limits and Specifications

Domestic television receivers are exempt from registration and the requirements of the proposed regulations, providing the dose rate at 5 cm from any outer surface is less than 0.5 mrem/hour.

General Guidance

None.

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SECTION III. LASERS

LASER/MASER HAZARDS

Department of the Air Force
Air Force Regulation No. 161-24 and memo from Colonel Henry C. Dorris clarifying the regulation, January 12, 1967 and memo March 20, 1967.

Type: Class A. Regulation of the Air Force.

Intended Compliers: Air Force Systems Command (AFSC), Air Force Logistics Command (AFLC) and the Air Force Using Command (AFUC).

Intended Benefitters: Military and civilian personnel.

Limits and Specifications

The "retinal hazard exposure level" for a ruby laser Q-switched with a pulse duration of 10 to 100 ns is given as an energy density of 0.125 J/cm^2 incident on the retina. In calculating the exposure to the retina, an iris diameter of 7 mm under night conditions and 3 mm for daylight conditions is to be used. In situations where beam enhancement may occur, the calculations should assume the possibility that the energy to the retina may be 100 times greater than what would be otherwise expected.

General Guidance

This regulation gives minimum requirements for medical surveillance in connection with lasers, gives guidance on

hazard assessment, and assigns responsibilities for evaluation and controlling laser/maser hazards as they apply to AFSC, AFLC, and the AFUC. The Air Force Surgeon General is directed to establish safe laser radiation exposure levels, standardize protective devices, and cooperate with other government agencies to evaluate laser hazards. Other Air Force organizations will provide safety rules and procedures.

Laser System Registration Law

State of Illinois

Laser System Registration Law available from Division of Sanitary Engineering, Department of Public Health, State of Illinois, Approved August 11, 1967.

Type: Class A. Illinois statutory law.

Intended Compliers: All operators of laser systems. "Operator" is an individual, group of individuals, partnership, firm, corporation, or association operating or supervising the operation of a laser system.

Intended Benefitters: Personnel working with or in the general vicinity of lasers and the general public.

Limits and Specifications

No numerical values given. Act enables the State Director of Public Health to exclude registraton of those lasers "where there is low-level energy output. . .or where. . .the public health hazard of the laser system is absent or negligible."

General Guidance

An act to require registration of laser systems; to

authorize the Department of Public Health to investigate and inspect all laser systems in the State; to require reporting of any accidental injuries sustained by such laser systems; and to provide injunctive relief and penalties for violations of this act.

Laser Systems - Code of Practice

Chief, Safety Officer, Ministry of Aviation, London, England
British Ministry of Aviation Laser Systems - Code of Practice, 1965 Ed., Shell Mex. House, London, W.C. 2.

Type: Class A. Code of Practice of the British Ministry of Aviation.

Intended Compliers: Department of the British Ministry of Aviation, England.

Intended Benefitters: The general public and workers who come in contact with lasers.

Limits and Specifications

Maximum permitted exposure to laser energy:

Condition	Type of pulse	Time or pulse duration	Permitted energy density falling on retina
1.	Single pulse	0.001 to 1 μs	0.001 J/cm^2
2.	Single or train of pulses	1 to 1,000 μs	0.01 J/cm^2
3.	Pulses or trains of pulses	0.1 s	0.1 J/cm^2

(continued)

Condition	Type of pulse	Time or pulse duration	Permitted energy density falling on retina
4.	Continuous-wave laser power incident upon the retina shall not exceed that value which makes ab = 1.0; where a = power at the retina (W/cm^2) and b = greatest dimension of the image on the retina (mm).		
5.	Any part of body except eye - total incident laser energy during any 1-second period shall not exceed 0.1 J/cm^2.		

Acceptable alternatives to the above conditions:

Condition 1.

Where the eye cannot resolve the image, the energy density at the pupil of the eye must not exceed 0.02 $ergs/cm^2$ indoors or 0.2 $ergs/cm^2$ in bright sunlight out-of-doors. Where the eye can resolve the image from a diffuse reflector, viewing is permissible if the energy density at the diffuse reflector does not exceed 0.03 J/cm^2 indoors or 0.3 J/cm^2 in bright sunlight out-of-doors. These levels must be reduced threefold if optical glint occurs.

Condition 2.

Same as alternatives to Condition 1, except permissible energy density is increased by a factor of 10.

Condition 3.

A continuous-wave laser of power output less than 50 μW may be viewed under any conditions.

General Guidance

The code requires the establishment of "laser - restricted area" around each laser installation unless it can be shown that under conditions likely to prevail no person can receive from the laser installation, radiation exceeding those specified in the code. Specific protection programs

are given for the general public with respect to long range (outdoor) laser setups and for laboratory laser systems.

Code of Practice for Research Lasers

Department of Supply Defence Standards Laboratories, Commonwealth of Australia

Defence Standards Laboratories, Department of Supply, Commonwealth of Australia, Administrative Memorandum No. 29 of 1966.

Type: Class A. Code of practice for Australian Defence Standards Laboratories.

Intended Compliers: All users of research lasers in the Defence Standards Laboratories, Australia.

Intended Benefitters: All personnel who use or work in the vicinity of lasers in the Defence Standards Laboratories, Australia.

Limits and Specifications

Energy flux density at the pupil of the eye is required to be less than:

2 ergs/cm^2 for pulsed lasers, and

1 μW for continuous lasers.

General Guidance

The code specifies that only an operator may view a laser beam with or without attenuation and then only after two appropriate professional officers have ascertained by calculation that there is no risk of damage to the eye (that the exposure limits are met). Requirements for eye examinations, reporting of incidents, electrical hazards, enclosures, and operating instructions are also given.

A Guide for Uniform Industrial Hygiene Codes or Regulations for Laser Installations

American Conference of Governmental Industrial Hygienists (ACGIH)

Supplement Number 7 to "A Guide for Uniform Industrial Hygiene Codes or Regulations," issued by ACGIH April 1949 and revised May 1965 and 1968.

Type: Class B. Recommendations of the ACGIH.

Intended Compliers: Laser users.

Intended Benefitters: Personnel in the laser control area and other persons likely to be exposed to laser radiations and associated hazards.

Limits and Specifications

Maximum permissible exposure levels for laser radiation at the cornea for direct illumination or specular reflection at wave length = 6943 Å.

Condition	Q-switched 1 ns to 1 μs pulse (PRF[a] <10) (ergs/cm^2)	Non-Q-switched 1 μs to 0.1 s pulse (PRF[a] <10) (ergs/cm^2)	Continuous-wave exposures (μW/cm^2)
Daylight (3-mm pupil)	0.5	5.0	50
Laboratory (5-mm pupil)	0.2	2.0	20
Night (7-mm pupil)	0.1	1.0	10

[a]PRF is "pulsed reoccurence frequency."

These levels can be adjusted for other wavelengths by using a graph (given in the document) of energy transmitted to and absorbed by the retina. A table is given which lists the maximum power or energy density for which adequate protection is afforded by glasses of optical density 1 through 9.

Maximum illuminance permitted for direct viewing from a diffuse surface reflection as measured at the reflecting surface.

Condition	Q-switched pulse (J/cm^2)	Non-Q-switched pulse (J/cm^2)	Continuous-wave laser (W/cm^2)
Daylight (3-mm pupil)	0.45	5.5	13.5
Laboratory (5-mm pupil)	0.15	2.0	6.0
Night (7.5-mm pupil)	0.070	0.9	2.5

General Guidance

Recommendations are made on exposure criteria, associated hazards involved in laser operations, hazards controls, personal protection, ventilation, electrical hazards, medical surveillance, and hazards evaluation.

LASER/MASER HAZARDS

Ground Electronics Engineering - Installation Agency Standard, U.S. Air Force

T.O. 31Z-10-4, Technical Manual, Electromagnetic Radiation Hazards, Change 1 Notice, Chapter 3, Section VII, Paragraphs 3-254 to 3-262, August 1, 1966.

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Type: Class C. General guide on laser hazards.

Intended Compliers: Air Force personnel using or working near lasers.

Intended Benefitters: Air Force personnel.

Limits and Specifications

None.

General Guidance

Discusses general safety precautions in the use of lasers and where to seek guidance on the subject.

LASER SAFETY

U.S. Atomic Energy Commission (AEC)
Draft of an addition to the AEC Standard Operating Procedure at the Nevada Test Site (NTS), NTSO-05X1, February 8, 1968.

Type: Class C. Draft of an addition to the AEC Standard Operating Procedure, Nevada Test Site Organization, based on the recommendations made by the Laser Safety Conference held on October 19-20, 1967, at Las Vegas, Nev.

Intended Compliers: Users of lasers at the Nevada Test Site.

Intended Benefitters: Personnel working at the test site and the offsite population.

Limits and Specifications

Type of laser	Type of pulse	Duration of single pulse	Permitted energy or power density directly falling on cornea
Infrared (>14,000 Å)	Single	Not specified	0.1 J/cm^2/pulse
	Continuous	--	1.0 W/cm^2
Visible and near infrared (4,000 to 14,000 Å)	Pulses with an off time between pulses of ≥100 ms	<100 ns	0.1 W/cm^2 peak power
		≥100 ns	0.1 $ergs/cm^2$ per pulse
	Continuous	--	3 $\mu W/cm^2$
Ultraviolet (<4,000 Å)	Not specified	Not specified	0.5 $\mu W/cm^2$ average power

For lasers operating in the ultraviolet, visible, near infrared, and infrared portions of the spectrum, the maximum intensity incident on the skin, excluding the eye, is 0.1 J/cm^2/pulse or 1.0 W/cm^2 for continuous-wave lasers.

General Guidance

Responsibilities and general procedures for laser safety associated with NTS programs are given. All lasers used at NTS are required to be registered except continuous-wave lasers equal to or below 2 mW total beam power.

Eye and Skin Protection, Environmental Exposures, and Electrical Hazards

Laser Safety Conference, Cincinnati, Ohio, January 29 to 31, 1968

Recommendations of the Workshops on Eye Protection and Environmental Exposures, Skin Protection and Electrical Hasards held at the Laser Safety Conference, University of Cincinnati, sponsored by the Medical Laser Laboratory

of the Children's Hospital of the University of Cincinnati, National Center for Urban and Industrial Health of the U.S. Public Health Service and the Department of Environmental Health of the College of Medicine of the University of Cincinnati.

Type: Class C. Recommendations made at a Laser Safety Conference.

Intended Compliers: Users of lasers.

Intended Benefitters: Personnel working in installations or areas containing lasers.

Limits and Specifications

Suggested conservative guidelines for permissible irradiation at the cornea for a wavelength of 6943 Å are as follows:

Laser type	3-mm pupil diameter	7-mm pupil diameter
Q-switched pulsed ($ergs/cm^2$)	0.5	0.1
Non-Q-switched pulsed ($ergs/cm^2$)	5.0	1.0
Continuous-wave ($\mu W/cm^2$)	5.0	1.0

For all lasers operating in the visible, near infrared, and infrared ranges, the maximum intensity incident on the skin, excluding the eye shall be:

0.1 J/cm^2/pulsed lasers, and

1.0 W/cm^2 for continuous-wave lasers.

General Guidance

Mention was made of the different means of eye protection and the need for proper identification and labelling of laser goggles. For environmental evaluation of byproducts produced by laser impacts on various target materials it was recommended that standard industrial hygiene, analytical, toxicological, health physics and microbiological methods be used. Electrical hazards need to be further defined and worked on but the knowledge required to solve such problems is available.

The Evaluation of Laser Hazards

David H. Sliney and William A. Palmisano
Presented at the American Industrial Hygiene Association Meeting, Chicago, Ill., May 14, 1967.

Type: Class C. Guide suggested by author.

Intended Compliers: Laser users.

Intended Benefitters: Personnel using or working near lasers.

Limits and Specifications

Permissible occupational exposure levels for laser radiation at the cornea for direct illumination or specular reflection at a wavelength of 6943 Å are listed on the following page. The values are considered to include a safety factor of 10. These levels can be adjusted for other wavelengths by using graphs of energy transmitted to, and absorbed at, the retina and normalizing the curve at 6943 Å. These adjusted levels should not exceed the above corresponding levels by a factor greater than 10. As a guideline, permissible exposure levels for the skin should not exceed the

nighttime levels for the eye by a factor of more than 10^5, ultraviolet excepted.

Laser type	Daylight 3-mm pupil	Laboratory 5-mm pupil	Night 7.5-mm pupil
Q-switched pulse ($ergs/cm^2$)	0.5	0.2	0.1
Non-Q-switched pulse ($ergs/cm^2$)	5	2	1
Continuous-wave ($\mu W/cm^2$)	5	2	1

General Guidance

General environmental and personal protective safeguards are given which apply to many laser situations. Also included are specific precautions to be followed when using high-powered lasers, low-powered gas and continuous-wave semiconductor lasers, CO_2-N_2 lasers, and outdoor laser set-ups. A method of hazard evaluation for the eye is given along with guidance on exposure control.

What You Should Know About Laser Safety

Martin-Marietta, Orlando Division
OR 6672-9/65, Rev. 11/65, Martin-Marietta, Orlando Division

Type: Class C. Martin-Marietta Company Guide.

Intended Compliers: Laser users.

Intended Benefitters: Occupational workers and visitors to laboratory.

Limits and Specifications

Eye safety level:

Pulse duration	Permitted energy density falling on the retina
30 ns	0.01 J/cm^2
Continuous-wave	0.1 J/cm^2 during any period of 0.1 s

General Guidance

Specific eye hazard nomograms to evaluate exposure hazards, general safety rules for pulsed (solid state), gas, and injection lasers, and personnel protective devices are given.

GUIDELINES FOR THE SAFE USE OF LASERS

F. X. Worden, W. C. Roberts, M.D., and J. P. Dunn, M.D.
General Medical Director's Organization, Western Electric Company

Type: Class C. Western Electric Company guide.

Intended Compliers: Western Electric Company employees using or working near lasers.

Intended Benefitters: Western Electric Company employees.

Limits and Specifications

The guideline states that not enough is known about laser damage to the eye to set definite exposure limits but that some suggested permissible exposure limits may be found in the Martin-Marietta laser safety booklet, the Ministry of

Aviation Code of Practice for laser systems, or in an article by Leon Goldman, M.D., entitled "Personnel Protection from High Energy Lasers," in the American Industrial Hygiene Association Journal of November-December 1965, page 553.

General Guidance

Responsibilities are assigned to the various organizations within the company (Engineering, Medical, Industrial Hygiene, Safety, and Purchasing) to follow appropriate procedures related to lasers. Each is designated appropriate tasks related to laser safety so that the company has a unified, comprehensive laser safety program. Instructions for each organization are somewhat general; details are worked out through interorganization cooperation.

Personnel Protection from High-Energy Lasers

Leon Goldman, M.D. and Peter Hornby
American Industrial Hygiene Association Journal, 26:553-557 (November-December 1965).

Type: Class C. Guide suggested by author.

Intended Compliers: Laser users.

Intended Benefitters: Personnel using or working near lasers.

Limits and Specifications

This paper gives "safe energy levels" for eye damage which the authors state are presently used. These are listed on the following page.

Type of laser	Energy density or power density falling on the cornea
Gas laser (6328 Å)	1 $\mu W/cm^2$
Pulsed ruby laser (6943 Å)	1 erg/cm^2
Pulsed neodymium laser (10,600 Å)	10 $ergs/cm^2$
Q-switched ruby laser (6943 Å)	0.1 erg/cm^2

General Guidance

This paper gives guidance on a laser protection program which centers on personnel control (eye protection, skin protection, protection from air contamination because of the use of lasers), and area control (avoidance of specular reflectance, proper ventilation, and avoidance of electrical shock). shock).

HAZARDS OF LASER RADIATION: MECHANISMS, CONTROL AND MANAGEMENT

Martin S. Litwin, Samuel Fine, Edmund Klein, Ben F. Fine, and Harold Raemen

American Industrial Hygiene Association Journal, 26:1:68-75 (January-February 1967).

Type: Class C. Guide suggested by author.

Intended Compliers: Laser users..

Intended Benefitters: Personnel using or working near lasers.

Limits and Specifications

A minimal threshold dose of radiation required to produce injury is suggested as a useful guideline for protec-

tion, as far as short-term effects are concerned. The statement is made that, in general, the retinal damage threshold dose for a 6943 Å non-Q-switched millisecond exposure is within the range of 0.5 to 1 J/cm^2 calculated to be incident on the retina. Injury threshold at high-peak-power levels using a Q-switched system appears to decrease with decreasing pulse duration. These data used with a safety factor of at least 100 provide guidelines for radiation protection standards at the ruby laser wavelength.

General Guidance

This paper gives guidance on the control of laser hazards through general administrative procedures (personnel, medical supervision, records), laboratory design, protection standards, and dosimetry.

SAFEGUARDING LASERS

Milton M. Zaret, M.D.
National Safety News, February 1965.

Type: Class C. Guide suggested by author.

Intended Compliers: Laser users.

Intended Benefitters: Personnel using or working near lasers.

Limits and Specifications

No exposure limits are given.

General Guidance

This article includes a compilation of recommended safe practices for laser users prepared by T. H. McBrien, Safety Supervisor, Aerospace Division of Westinghouse Electric Cor-

poration and member of the Chesapeake Chapter, A.S.S.E. The compilation includes recommendations from the Association of Casualty and Surety Companies, Bell Telephone Laboratories, Leonard R. Solon, Dr. Milton Zaret, and Michael Sykos.

Laser Safety Considerations

P. Brown, Jr.
RCA Laboratories, Princeton, New Jersey, July 8, 1966.

Type: Class C. Guide suggested by author.

Intended Compliers: Personnel using or working near lasers.

Intended Benefitters: Personnel using or working near lasers.

Limits and Specifications

The report states that there is no general agreement with respect to safe exposure levels. Some upper levels are suggested, however, for light incident on the cornea:

Pulse duration	Suggested upper limit of power density incident on the cornea
Milliseconds and shorter	500 $\mu W/cm^2$ peak power density
Continuous-wave	500 $\mu W/cm^2$

General Guidance

Eye protection and a hazards control program are the two main subjects of the report. The report lists precautions to be observed when protective goggles are used, and also contains some general guidelines for safety procedures to prevent accidental exposure to laser radiation in the laboratory.

SECTION IV. ULTRAVIOLET RADIATION

HEAD, EYE AND RESPIRATORY PROTECTION SAFETY CODE

United States of America Standards Institute
USASI - Z 2.1-1959.

Type: Class B. USASI standard.

Intended Compliers: Persons exposed to ultraviolet, infrared, and excessive visible radiation.

Intended Benefitters: Compliers and general public.

Limits and Specifications

Specifications are the same as those in:

Spectral-Transmissive Properties and Use of Eye-Protective Glasses
United States National Bureau of Standards
NBS Circular 471, October 8, 1948.

General Guidance

This standard incorporates specifications established by the National Bureau of Standards. NBS has numbered the various shades of filter lenses which correspond to specific spectral transmittances. Lenses which reduce the intensity of visible radiation should be used only where exposure to excessive sunlight or glare occurs. The use of tinted lenses inside homes and offices is not recommended since the level of illumination indoors is low. The use of dark glasses at night for reducing the glare from automobile headlights also

is considered inadvisable since the visibility of all other objects is reduced. In selecting glasses for industrial exposures, it should be noted that lenses which reduce visible light may not remove ultraviolet or infrared radiation produced in the industrial process.

A Standard Source of Ultraviolet Radiation for Calibrating Photoelectric Dosage Intensity Meters

United States National Bureau of Standards (NBS)
Research Paper RP858, Journal of Research of the National Bureau of Standards, 16:83-92 (February 1936).

Type: Class B. NBS Standard Source Description.

Intended Compliers: Manufacturers and users of sources of ultraviolet radiation.

Intended Benefitters: Manufacturers and users of sources of ultraviolet radiation.

Limits and Specifications

The ultraviolet output of the quartz mercury-arc lamp was regulated to 2 or 3 parts in 1,500, as measured with a photoelectric ultraviolet meter.

General Guidance

Abstract:

The advantages and disadvantages of sources emitting either a continuous or a discontinuous spectrum are considered in connection with the use of such lamps as a standard of ultraviolet radiation.

It is shown that because of the high intensity and favorable distribution of ultraviolet emission lines at 2967 to 3132 Å, the quartz mercury-arc lamp is well adapted for

standardizing photoelectric ultraviolet dosage intensity meters in absolute units.

A description is given of the installation of a commercial 110-volt vertical quartz mercury Uviarc lamp and of methods to calibrate its ultraviolet output in absolute units.

By calibrating photoelectric ultraviolet intensity meters against a laboratory standard, a great reduction is effected in equipment required for field measurements of ultraviolet solar radiation.

Acceptance of Ultraviolet Lamps for Disinfection Purposes

American Medical Association (AMA)
Report of the Council on Physical Medicine
Journal of the American Medical Association, 137:1600-1603 (August 28, 1948).

[This report is an authorized revision of the previous statement "Acceptance of Ultraviolet Lamps for Disinfecting Purposes," JAMA 122, 503 (June 1943).]

Type: Class C. AMA Acceptance Requirement.

Intended Compliers: Manufacturers of ultraviolet lamps and users in hospitals, nurseries, and operating rooms.

Intended Benefitters: Patients, staff, and bystanders in hospitals, nurseries, and operating rooms.

Limits and Specifications

The total intensity of ultraviolet radiation emanating directly from the lamp and diffusely reflected from the walls and fixtures incident on the occupant for 7 hours or less should not exceed five-tenths microwatt per square centi-

meter (0.5 $\mu W/cm^2$) and for continuous exposure (24 hours a day) should not exceed 0.10 microwatt per square centimeter of wavelength 2537 Å.

The data governing the Council's acceptance of sun lamps show that exposure to an intensity of 36 microwatts per square centimeter of radiation of wavelength 2537 Å produces an erythema in about 15 minutes.

General Guidance

The total amount of direct and scattered ultraviolet radiation incident on the occupants must be kept below the level that will produce conjunctivitis, erythema, or any other injurious physiologic effects that may arise from prolonged irradiation. This requirement should be met by a suitable arrangement of the lamp fixtures and light baffles and not by requiring the occupants of hospital wards and nurseries to wear glasses and a special covering of the parts of the body (face, hands) normally uncovered.

Recent developments indicate that reflected ultraviolet intensities in excess of that specified by the Council should be remedied by painting all ordinary and all perforated acoustic ceilings with a standard oil paint or by painting nonperforated acoustic materials with a coat of ordinary glue wall size.

Requirements for Acceptance of Ultraviolet Lamps for Disinfecting Air

Clinical evidence submitted to the Council shows that under properly controlled conditions the killing of airborne micro-organisms by ultraviolet rays may be used to supplement other methods of disinfecting air, for the prevention of cross-infection, and in contagious wards in nurseries and hospitals, for reducing airborne infection of wounds in operating rooms. The deleterious effects of ozone generated by ultraviolet lamps are recognized. The Council

therefore requires for acceptability of ultraviolet disinfecting lamps that, under suitable ventilation, in the space near the occupants of the room the concentration of ozone shall not exceed 1 part in 10 million; however, in view of the researches by Witheridge and Yaglou showing that a much lower concentration (1 part in 25 million) is irritating to the mucous membranes of the upper respiratory tract, this specification of 1 part in 10 million is tentative, awaiting confirmation of the evidence that a lower concentration of ozone is desirable in nurseries and hospital rooms occupied 24 hours a day. If the odor of ozone is distinctly perceptible, the Council recommends increased ventilation.

Recently, manufacturers have agreed on the manufacture of two kinds of ultraviolet disinfecting lamps: (1) the type "L" lamp that generates a low amount of ozone and (2) the type "H" lamp that produces a high amount of ozone. The Council only accepts the type "L" lamp, which generates practically no ozone.

In considering ultraviolet generators for disinfecting purposes, the Council makes no distinction between lamps for the use in air-conditioning ducts and lamps for use in open rooms in which there is only a slow circulation of air. In both cases, a sufficient number of lamps must be provided to insure adequate disinfection of the air as determined by approved culture tests or other accepted procedures. So that an ultraviolet output above the minimum value for adequate disinfection may be maintained, the Council recommends that the ultraviolet intensity of each lamp unit be measured at least once a month. To comply with the Council's requirements, the ultraviolet spectral energy distribution of the disinfecting lamp shall be comparable in lethal effectiveness with the low vapor pressure mercury discharge tube in which the dominant radiation is of wavelength 2537 Å.

The minimum intensity at right angles to and at 1 meter from the plane of the lamp tube in its fixture shall not be less than the germicidal equivalent of 20 microwatts per square centimeter of homogeneous radiation of wavelength 2537 Å. The useful life of the lamp shall not be less than 4,000 hours. During this period the ultraviolet output shall not fall below the specified minimum intensity. To meet this requirement the lamp may be provided with a voltage regulator to compensate for the decrease in intensity of ultraviolet radiation with usage; or the lamp may emit a sufficient excess of ultraviolet radiation when new, so that the output shall not fall below the specified minimum value (20 $\mu W/cm^2$ at 1 meter) in less than 4,000 hours of operation. In either case, the installation shall be provided with adequate safeguards against overexposure of the occupants of the room to ultraviolet radiation. The burner of the lamp shall be of glass or of suitable filter jacketed quartz, highly transparent to the emission line at 2537 Å, and opaque to radiation of wavelengths shorter than 2200 Å, to prevent the generation of an injurious amount of ozone, which is largely produced by these short wavelengths. To insure compliance with these requirements, the lamp may consist of one, two, or three tubes, mounted and operated as a unit.

For consideration of acceptance by the Council, the manufacturer shall submit a lamp unit in its fixture, permanently marked as to its useful life and its radiant flux in microwatts per square centimeter of wavelength 2537 Å, at 1 meter under the normal power input used to insure a useful life of not less than 4,000 hours. In addition the manufacturer shall submit satisfactory clinical evidence, obtained over a period of not less than 4 winter months, of the effectiveness of an installation of such lamps in maintaining adequately sterilized conditions in the space (hospital, nursery) subjected to radiant disinfection.

Spectral-Transmissive Properties and Use of Eye-Protective Glasses

United States National Bureau of Standards
Circular 471 by Ralph Stair (supersedes Circular C421)
October 8, 1948.

Type: Class C. NBS guide.

Intended Compliers: Manufacturers, users and persons otherwise exposed to harmful ultraviolet, visible, or infrared radiation.

Intended Benefitters: Users and other persons exposed.

Limits and Specifications

Tables and graphs from which safe limits can be derived are given in the document.

General Guidance

This paper contains spectral - transmissive data on most of the widely distributed brands and types of glasses employed in protecting the eyes from harmful ultraviolet, visible, or infrared radiant energy that may be encountered. The standardization of shade numbers for protective glasses used in industry, glasses for special welding operations, the use of colored glasses for night driving, and the elimination of glare in sunlight are given considerable attention.

SECTION V. MICROWAVES

RADIO FREQUENCY DEVICES

Federal Communications Commission (FCC)
Code of Federal Regulations, Title 47, Part 15.

Type: Class A. U.S. Government regulation.

Intended Compliers: Radio stations that may interfere with radio communications, and manufacturers.

Intended Benefitters: Radio stations and general public.

Limits and Specifications

Type of apparatus	Frequency range	Field strength (μV/m)
Radio receivers (Applies only to receivers that operate between 30 - 890 MHz	0.45- 25 MHz	(a)
	25 - 70 MHz	32 at 100 ft.
	70 - 130 MHz	50 at 100 ft.
	130 - 174 MHz	50-150 at 100 ft. (linear interpolation)
	174 - 260 MHz	150 at 100 ft.
	260 - 470 MHz	150-500 at 100 ft. (linear interpolation)
	470 - 1000 MHz	[b]500 at 100 ft.
Community antenna	Up to 54 MHz	[c]15 at 100 ft.
	54 - 132 MHz	[d]20 at 10 ft.
	132 - 216 MHz	[d]50 at 10 ft.
	Over 216 MHz	15 at 100 ft.

(continued)

Type of apparatus	Frequency range	Field strength (μV/m)
Low-power communication devices (miniature transmitters)	10 - 490 Hz	$2400/F_{Hz}$ at 1,000 ft.
	Alternative for 160 - 190 Hz	1 watt input and 50-ft. antenna
	510 - 1600 Hz	$24,000/F_{Hz}$ at 100 ft. or 100 milliwatts input and 10-ft. antenna
	26.97 - 27.27 MHz	(e)
	Above 70 MHz	(f,g)
Radiocontrols for door openers (garage door controls)	Below 70 MHz[i] Above 70 MHz[i]	(h) (f)
Wireless microphones and telemetering devices	88 - 108 MHz	(j)
All other restricted	All frequencies	15 at $\lambda/2\pi$; $\lambda/2\pi$ = $157,000/F_{Hz}$ ft.

[a]In lieu of field strength, a maximum powerline RF voltage is specified.

For TV receivers at all frequencies: 100 μV

For all other receivers:

0.45 - 9 MHz	100 μV
9 - 10 MHz	100 to 1,000 μV (linear interpolation)
10 - 25 MHz	1,000 μV

[b]For television receivers the limit 500 μV/m is temporarily increased to 1,000 μV/m. All other receivers must comply with the 500 μV/m limit.

[c]In a sparsely inhabited area (an area where TV signals are not in fact being received within 1,000 ft. of the system), this value is increased to 400 μV/m at 10 ft.

[d]In a sparsely inhabited area (an area where TV signals are not in fact being received within 1,000 ft. of the system), this value is increased to 1,000 μV/m at 10 ft.

[e]The FCC regulations do not specify a field strength. In lieu thereof, operation is limited to a maximum of 100 milliwatts input to the final RF stage with a single element antenna not more than 5 ft. long.

[f]These devices must meet the field strength limitations prescribed for receivers up to 1,000 MHz. Above 1,000 MHz, the field strength must not exceed 500 μV/m at 100 ft.

[g]Radiation must be limited to a 1-second duration followed by at least a 30-second silent period.

[h]Operation is limited to frequencies and conditions specified for Low-Power Communication Devices.

[i]Radiation is prohibited in the following frequency bands:

MHz	MHz	GHz
73 - 75.4	608 - 614	10.68 - 10.70
108 - 118	960 - 1,215	15.35 - 15.4
121.4 - 121.6	1,400 - 1,427	19.3 - 19.4
242.8 - 243.2	1,535 - 1,670	31.3 - 31.5
265 - 285	2,690 - 2,700	88 - 90
328.6 - 335.4	4,200 - 4,400	
404 - 406	4,990 - 5,250	

[j]Radiation within a 200 Hz band centered on the operating frequency must not exceed 50 μV/m at 50 ft. All other radiation is limited to 40 μV/m at 10 ft.

Industrial, Scientific and Medical Equipment That May Interfere With Radio Communications

Federal Communications Commission (FCC)
Code of Federal Regulations, Title 47, Part 18

Type: Class A. U.S. Government regulation.

Intended Compliers: Users of industrial, scientific, and medical (ISM) equipment that may interfere with radio communications.

Intended Benefitters: General public and users of equipment.

Limits and Specifications

The following frequencies are allocated for ISM equipment use with the tolerance limits specified:

Frequency (MHz)	Tolerance
13.56	6.78 KHz
27.12	160 KHz
40.68	20 KHz
915	25 MHz
2,450	50 MHz
5,800	75 MHz
22,125	125 MHz

The energy radiated within the bands defined by these tolerances is not limited for the frequency bands below 915 MHz. For the frequency bands of 915 MHz and above, the energy radiated and the bandwidth of emissions shall be reduced to the greatest extent practicable.

The energy radiated at frequencies outside the above bands shall be limited as follows:

1. *Industrial Heating Equipment*

The radiated energy on any frequency below 5,725 MHz, except ISM frequencies, shall not exceed 10 μV/m at a distance of 1 mile from the equipment.

2. *Medical Diathermy Equipment*

a. For equipment operating at 13.56, 27.12, or 40.68 MHz, spurious and harmonic radiated energy shall not exceed 25 μV/m at a distance of 100 ft. from the equipment.

b. For equipment operating on unassigned frequencies, radiated energy shall not exceed 15 μV/m at a distance of 1,000 ft. from the equipment.

3. *Ultrasonic Equipment*

a. Radiated energy of frequencies:

(1) Up to and including 490 Hz shall not exceed $(2{,}400 \div \text{Frequency in KHz})^{1/2}$ μV/m at a distance of 1,000 ft. If

the equipment is using RF power in excess of 500 W, the limit may be increased by (Generated Power ÷ 500)$^{1/2}$ provided that the radiated energy does not exceed 10 μV/m at a distance of 100 ft.

(2) Above 490 KHz up to and including 1,600 KHz, shall not exceed (2,400 ÷ Frequency in KHz) μV/m at a distance of 100 ft.

(3) Above 1,600 KHz, exclusive of ISM bands, shall not exceed 15 μV/m at a distance of 100 ft.

b. Conducted energy on power lines at frequencies:

(1) Up to 490 Hz shall not exceed 1,000 μV.

(2) Above 490 Hz shall not exceed 200 μV.

4. *RF Welders*

Temporary limit of 10 μV/m at 1 mile pending final acting in Docket No. 11467.

5. *Miscellaneous Equipment*

Same as medical diathermy equipment. For equipment generating power in excess of 500 W, the limit is increased by (Generated Power ÷ 500)$^{1/2}$ provided that the radiated energy does not exceed 10 μV/m at a distance of 1 mile.

General Guidance

The regulations (1) set forth the conditions under which the operation of equipment is considered not to cause interference and is therefore not required to be licensed and (2) provide a licensing procedure for ISM equipment whose operation is a source of interference.

For operation without a license, the equipment must operate without causing interference to the communications of any licensed station.

The operator of an ISM equipment which causes harmful interference to an authorized radio service shall promptly

stop operating the device. Operation shall not be resumed until the condition causing the harmful interference has been eliminated.

The equipment must be type approved or certificated and the equipment and the location must be available for inspection.

TELECOMMUNICATIONS

Federal Communications Commission (FCC)
Code of Federal Regulations, Title 47, Parts 70 - 79.

Type: Class A. U.S. Government regulation.

Intended Compliers: Operators of civilian telecommunications devices.

Intended Benefitters: Operators and general public.

Limits and Specifications

Radiations emitted from antennas to meet power requirements. The maximum power output from AM broadcast transmitters is 50 kW from 535 to 1605 kHz with assignable frequencies every 10 kHz starting at 540 kHz and ending at 1600 kHz. This may result in signal strengths of tens of volts per meter at 0.1 mile from the antenna.

For FM broadcast transmitters (88 to 108 MHz), the maximum allowed radiated power is 100 kW. At 1 mile from a dipole antenna 2,000 feet above the surrounding terrain emitting 100 kW, the field strength 30 feet above the local terrain would be about 1 volt per meter; and at 10 miles about 0.1 volt per meter. In practice the antenna at an FM station is not a simple dipole but is directive in the vertical plane with the beam directed at or within 2° below the horizon.

The fields computed above (in the main beam) are nearly 2,000 feet above ground at 1 mile and the field strength received on the ground will be considerably less, the actual value depending on the directivity of the antenna.

The maximum power that commercial television stations can emit is 5 MW, in the 470 to 890 MHz range. The corresponding field strength at 1 mile (30 feet above the ground when the transmitting antenna is a dipole 2,000 feet above the local terrain) is about 20 V/m and at 10 miles is about 2 V/m.

In practice, the TV antenna is directive in the vertical plane and the same remarks about the close-in field apply to TV stations as apply to FM stations.

International broadcast radio stations are allowed to operate on certain frequencies, the highest of which is 26.1 MHz. The allowable power is that needed to achieve the desired communication in line with good engineering judgment and practice.

The powers specified for experimental, auxiliary, and special broadcast services restrict operation to that necessary to maintain desired communication using good engineering judgment and practice. In nearly all cases, the desired communication can be achieved with relatively low power. The maximum specified power was 100 watts for a TV related auxiliary station.

General Guidance

Each type of telecommunications service must conform to specifications given for design of equipment, monitoring and operating standards, assigned frequencies, and power levels. These specifications are intended to achieve the power at assigned frequencies required to assure reception of the radio signals at distances over which the station is assigned coverage by the FCC, and at the same time to minimize or eliminate interference with other stations.

Addendum

There are several categories of high-power (megawatt range) stations operated by the U.S. Government. The International Broadcast stations administered by the United States Information Agency (USIA) operate in the same frequency range as the international broadcast stations licensed by the FCC, but the USIA stations use vastly higher powers.

A second group is the low-frequency Loran stations operated by the Coast Guard. These stations radiate about 2 to 5 MW from towers up to 1,000 feet in height in the 90 to 110 kHz frequency range.

A third group is the megawatt-powered VLF (below 30 kHz) communication stations operated by the U.S. Navy for round-the-world communication.

ELECTROMAGNETIC RADIATION HAZARDS

Technical Manual on Ground Electronics
Engineering - Installation Agency Standard
(GEEIA Standard)
United States Air Force (USAF)
T.O. 31Z-10-4, August 1966
Replaced T.O. 31Z-10-4, October 1, 1961.

Type: Class A. U.S. Air Force Standard.

Intended Compliers: Engineers and operators for Air Force ground electronics.

Intended Benefitters: U.S. Air Force and general public.

Limits and Specifications

0.01 watt/cm^2 of radio frequency power is considered to be hazardous.

All electronic devices or tubes capable of producing external x-radiation in excess of 300 mR/week shall be operated under adequate radiation-shielding conditions.

General Guidance

RF Radiation - The following general rules should be observed to prevent unnecessary exposure to microwave or RF radiation:

1. All areas in which an RF power density of 0.01 watt/cm^2 is suspected or detected shall be considered hazardous and will be posted with warning signs.

2. Limited occupancy is allowed in areas where the power density is between 0.01 and 0.1 watt/cm^2 (AFM 161-7). Great care must be exercised in the application of the criteria at these power levels since the consequences of accidental overexposure can be greater. A policy of prohibiting intentional exposure to power levels exceeding 0.01 watt/cm^2 is recommended. Areas in which the power density does not exceed 0.01 watt/cm^2 require no controls, such as permissible time factors, control of antenna rotation, and so forth.

3. Personnel shall be prohibited from working in the field of radiation of any energized antenna, waveguide, feedhorn structure, or transmission line where the measured power density exceeds 0.1 watt/cm^2. Theoretical calculations may be used for guidance, in lieu of actual measurements with test equipment.

4. The practice of discharging into the surrounding area the RF output of high-power generators producing average power levels of 0.01 watt/cm^2, or more, shall be discouraged. Dummy loads, water loads, or absorbent materials shall be used to absorb the energy output of such equipment while it is being tested.

5. Where test procedures require free-space radiation, the radiating device (antenna) must be positioned so as to direct the radiated beam away from inhabited structures or

other places where there are personnel. In the positioning of such radiating devices, care must be taken to avoid reflection of either the primary beam or accessory lobes in such a manner as to expose personnel in adjacent areas.

Ionizing Radiation - The following general rules should be observed to prevent unnecessary exposure to ionizing or x-radiation:

1. All electronic devices or tubes capable of producing external x-radiation in excess of 300 mR/week shall be operated in appropriate radiation-proof enclosures, unless such devices or tubes are properly shielded, and such shielding has been determined to be adequate for the protection of personnel. For purposes of equipment and installation design, shielding requirements shall be based on a maximum permissible exposure of 100 mR/week. This requirement is interpreted to mean that exposures to any part of the human body of 2.5 mR/hour cannot be exceeded, assuming a 40-hour work week.

2. The commander of any project or operation dealing with radioactive materials or equipment capable of producing x rays shall require the wearing of dosimetric devices by personnel who may be exposed to a possible radiation hazard, and shall see that their exposures are recorded. Areas should be checked by qualified experts to determine the level of ionizing radiation and, if found necessary, to establish time limits for personnel working in the area. Supervisors of sections that are designated as x-radiation hazardous areas shall keep the number of personnel in these areas to a minimum commensurate with proper maintenance and operating procedures.

3. Personnel working in x-radiation hazardous areas shall not be permitted to operate any electronic device or tube employing a peak plate voltage of 18 kV or higher with any of the shielding removed from the equipment, except where such operation is conducted in a satisfactory radiation-proof enclosure.

CONTROL OF HAZARDS TO HEALTH FROM MICROWAVE RADIATION

United States Army (USA) and United States Air Force (USAF)
Army Technical Bulletin TB MED 270
Air Force Manual AFM 161-7
December 1965.

Type: Class A. U.S. Army and U.S. Air Force regulation.

Intended Compliers: U.S. Army and U.S. Air Force personnel in the vicinity of microwave transmitting equipment.

Intended Benefitters: U.S. Army and U.S. Air Force personnel and general public.

Limits and Specifications

Occupancy	Average power density
Unlimited	<10 mW/cm^2
Limited[a]	10 to 100 mW/cm^2
Denied	>100 mW/cm^2

[a]Exposure time (minutes) during any 1-hour period = $6,000/x^2$, where x is the average power density in mW/cm^2.

General Guidance

When feasible, microwave beams should be located to minimize exposures in areas adjacent to and within military installations.

Note:

This regulation supersedes Air Force Pamphlet Number 160-6-13, issued by USAF Medical Service in May 1958.

Radiation Limits, Microwave and X Radiation Generated by Ground Electronic Equipment (As Related to Personnel Safety)

United States Air Force
MIL-R-9673 B (USAF), 15 September 1961.

Type: Class A. U.S. Air Force regulation.

Intended Compliers: U.S. Air Force personnel and contractors.

Intended Benefitters: U.S. Air Force personnel and general public.

Limits and Specifications

The supplier of the electronic equipment must define areas of specified RF power density 10 mW/cm^2, or greater.

Radiation limits are set only for x rays radiating at 2.5 mR/hour at 12 inches from an accessible surface.

General Guidance

The contractor shall provide information before and after equipment has been delivered describing the areas of radio frequency power densities greater than 0.01 W/cm^2. Requirements are included for x-ray shielding of the equipment to 2.5 mR/hour within 12 inches of an accessible surface. The survey equipment used for radio frequency and x rays shall be approved by the Air Force. Hazard signs shall be posted where x-radiation emanation is higher than that stated.

TECHNICAL MANUAL FOR RADIO-FREQUENCY RADIATION HAZARDS

Department of the Navy, Naval Ships Systems Command
NAVSHIPS 0900-005-8000, July 1966.

Type: Class A. U.S. Navy Manual.

Intended Compliers: U.S. Navy personnel.

Intended Benefitters: U.S. Navy personnel and general public.

Limits and Specifications

Continuous exposure: 10 mW/cm^2.

Intermittent exposure: 300 mJ/cm^2 for a 3-second interval.

General Guidance

Biological effects of radio frequency radiation are described. Equations are given for calculating the on-axis power density radiated from large-aperture antennas. Methods for measuring the power density are given.

SAFETY PRECAUTIONS FOR SHORE ACTIVITIES

United States Navy (USN)
NAVSO P-2455 April 1965.

Type: Class A. U.S. Navy Mandatory, Advisory and Supplemental Precautions.

Intended Compliers: U.S. Navy personnel.

Intended Benefitters: U.S. Navy personnel and general public.

Limits and Specifications

Continuous exposure: 10 mW/cm^2.

Intermittent exposure: 300 mJ/cm^2 per 3-second period of time. This is equivalent to 10 mW/cm^2 for a 30-second period.

General Guidance

Chapter 4, paragraph 0415-8 cautions against dangers associated with fueling aircraft near radar beams.

Chapter 15, paragraph 1543 - Radio Frequency Radiation Hazards - Radiated beams from antennas of electronic equipment can produce hazardous conditions such as shock, ignition of combustible materials, triggering electro-explosive devices, heating of objects in beam, and biological damage. Paragraph 1544 deals with x-radiation hazards from high-voltage electronic equipment. Paragraph 1545 deals with work on antennas. Paragraph 1546 deals with cathode-ray tubes. Paragraphs 1547 and 1548 deal with radioactive materials used with Radiac equipment.

Temporary Safety Regulations for Personnel in the Presence of Microwave Generators

U.S.S.R. Ministry of Hygiene
Publication Number 273-58, November 26, 1958.

Type: Class A. U.S.S.R. Ministry of Hygiene Regulation.

Intended Compliers: Users of microwave generators.

Intended Benfitters: Users of microwave generators and public.

Limits and Specifications

1. Irradiation during entire working day: 0.01 mW/cm^2.
2. Irradiation less than 2 hours per working day: 0.1 mW/cm^2.
3. Irradiation less than 15 or 20 minutes per working day: 1.0 mW/cm^2. In this case protective goggles are required.

General Guidance

Operating precautions and working area restrictions are presented for microwave equipment and laboratories. Instructions are given for periodic surveys, personal protection and medical examination.

Radio-Noise and Field-Strength Meters, 0.015 to 30 Megacycles/Second, Specifications for

United States of America Standards Institute (USASI)
USASI - C 63.2 - 1963.

Type: Class B. USASI Specification for Meter.

Intended Compliers: Manufacturers and users of radio equipment.

Intended Benefitters: Compliers.

Limits and Specifications

Not applicable.

General Guidance

This specification recommends the proper operating characteristics of instruments for measuring voltages and power at radio frequencies. The instruments are described. Criteria are established for sensitivity, accuracy, output

meter scale, antennas, input impedance, selectivity and bandwidth, and rejection of spurious signals.

Radio-Noise and Field-Strength Meters, 20 to 1,000 Megacycles/Second, Specifications for

United States of America Standards Institute (USASI)
USASI-C 63.3 - 1964.

Type: Class B. USASI Specification for Mete-.

Intended Compliers: Manufacturers and users of radio equipment.

Intended Benefitters: Compliers.

Limits and Specifications

Not applicable.

General Guidance

This specification recommends the proper operational characteristics of radio frequency voltage or power-measuring instruments.

The basic measuring set is briefly described. Criteria are established for sensitivity, accuracy, output meter scale, antennas, input impedance, selectivity and bandwidth, and spurious signal rejection. The time constants of the detector circuit are given for average, quasi-peak, and peak-reading circuits.

Radio-Noise Voltage and Radio-Noise Field Strength, 0.015 to 25 Megacycles/Second, Low Voltage Electric Equipment, and Nonelectric Equipment, Methods of Measurement of

United States of America Standards Institute (USASI)
USASI-C 63.4 - 1963.

Type: Class B. Standard for Measurement.

Intended Compliers: Manufacturers and Users of low-voltage electric and nonelectric equipment.

Intended Benefitters: Compliers.

Limits and Specificationns

Not applicable.

General Guidance

The standard defines conditions under which measurements may be made in the laboratory and in outdoor tests, and specifies the environmental noise level to be at least 6 db below the allowable limit of the applicable standard. Units of measurement for radio noise are in microvolts per meter.

Safety Level of Electromagnetic Radiation with Respect to Personnel

United States of America Standards Institute (USASI)
USASI-C 95.1 - 1966.

Type: Class B. USASI Standard.

Intended Compliers: Users of equipment emitting electromagnetic radiation.

Intended Benefitters: Users of equipment and general public.

Limits and Specifications

Power density: 10 mW/cm^2 for periods of 0.1 hour or more.

Energy density: 1 $mW\text{-}hr/cm^2$ during any 0.1-hour period.

Radiation characterized by a power level tenfold smaller will not result in any noticeable effect on mankind. Radiation levels which are tenfold larger than recommended are certainly dangerous.

General Guidance

The guide recommends exposure limit numbers for continuous or intermittent radiation under normal environmental conditions. The guide explains that the recommended exposure limits do not apply in all cases, such as in extreme environments, or when the persons exposed may have circulatory or other health problems. The formulated recommendations pertain to both whole-body irradiation and partial-body irradiation. The recommended exposure levels or below may be achieved by source modification, medium modification, or personal protection devices.

RADIO-FREQUENCY RADIATION HAZARD WARNING SYMBOL

United States of America Standards Institute (USASI)
USASI-C 95.2 - 1966.

Type: Class B. USASI Standard.

Intended Compliers: Users of equipment emitting biologically hazardous electromagnetic radiation.

Intended Benefitters: Users of equipment and general public.

Limits and Specifications

Not applicable.

General Guidance

The warning symbol shall consist of a red isosceles triangle above an inverted black isosceles triangle, separated and outlined by an aluminum color border. The words "Warning Radio-Frequency Radiation Hazard" snall appear in the upper triangle. Other warning information, at the discretion of the user, shall appear in the lower triangle.

Aircraft Fueling on the Ground

National Fire Protection Association (NFPA)
NFPA No. 407-1965
USASI No. Z119.1-1966.

Type: Class B. NFPA Standard and USASI Standard.

Intended Compliers: Aircraft fuelers.

Intended Benefitters: Aircraft fuelers and general public.

Limits and Specifications

None.

General Guidance

Among the precautions required for the various hazards associated with fueling aircraft on the ground are precautions applying to aircraft and personnel in the vicinity of radar beams.

Recommended Practice for Measurement of Field Intensity Above 300 Mc from Radio-Frequency, Industrial, Scientific, and Medical Equipment

American Institute of Electrical Engineers (AIEE)
IEEE 139 (formerly AIEE 950)
April 1952.

Type: Class B. IEEE Standard.

Intended Compliers: Users of industrial, scientific, and medical electronic equipment.

Intended Benefitters: Users and general public.

Limits and Specifications

Not applicable.

General Guidance

This is a recommended practice for accurate measurements of radio frequency generating equipment over 300 MHz.

The recommended practice gives a brief introduction to two fundamental methods of measuring field intensity using dipole, reflector, and horn antennas built to specifications in the report. General precautions and techniques are given regarding impedance matching, accuracy, and equipment associated with measurement.

Note:

The American Institute of Electrical Engineers (AIEE) and the Institute of Radio Engineers (IRE) merged into the Institute of Electrical and Electronics Engineers (IEEE) on January 1, 1963. As a result, all the AIEE standards were renumbered into a new IEEE series. AIEE No. 950, April 1952, was renumbered as IEEE 139, April 1952, with no change in title or in text.

RADIATION HAZARDS FROM ELECTRONIC EQUIPMENT

Canadian Standards Association (CSA)
CSA Standard Z65-1966.

Type: Class B. CSA Standard.

Intended Compliers: Manufacturers and users of electronic equipment.

Intended Benefitters: Users of electronic equipment and general public.

Limits and Specifications

Permissible levels of radiation for people from radio frequency fields.

For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 to 100,000 megahertz, the radiation level of 10 milliwatts per square centimeter as averaged over any possible 0.1-hour period shall not be exceeded. This means:

1. A power flux of 10 milliwatts per square centimeter for periods of 0.1 hour or more; and
2. An energy flux (total) of 1 milliwatt-hour per square centimeter for periods up to 0.1 hour.

This requirement applies whether the radiation is continuous or intermittent.

Permissible levels of radiation for people from ionizing radiation.

The exposure and cumulative exposure of persons to ionizing radiation shall be kept as low as possible.

An area where the dose for occupants could be in excess of 1.5 rems in a year shall be established as a control area.

Maximum permissible doses for individuals are given in detail in Publication 6 (1962) of the International Commission on Radiological Protection and in the Canadian Atomic Energy Control Regulations; however, for purposes of planning, the following maximum permissible doses to whole body, blood-forming organs, gonads, and eyes shall be observed:

1. For occupationally exposed persons:
   a. In any period of 13 consecutive weeks - 3 rem
   b. In any period of 52 consecutive weeks - 5 rem.
2. For all other persons, in 1 year - 0.5 rem.

Radio frequency radiation of electric blasting caps.

Tables and conditions are given for safe distances for various levels of radiated power.

General Guidance

Human body hazards from RF fields.

This part covers a method for preventing possible harmful effects on mankind, resulting from exposure to electromagnetic radiation in the frequency range of 10 to 100,000 megahertz. It applies to all radiations originating from radio stations, radar equipment, and other possible sources of electromagnetic radiation, such as those used for communication, radio navigation, and industrial and scientific purposes. It is not intended to apply to the deliberate exposure of patients by or under the direction of practitioners of the healing arts.

Hazards to humans from ionizing radiation.

This part applies to hazards from ionizing radiation produced incidentally by electronic components such as high-voltage rectifiers, cathode-ray tubes, television tubes, klystrons, magnetrons, thyratrons, and electronic tubes containing radioactive material. It does not apply to hazards from ionizing originating from x-ray or other electronic

equipment intended for the production of ionizing radiation or from radioactive material except as noted.

Electric blasting cap hazards from radio frequency radiation.

This part provides a standard of safe usage and transportation of electric blasting caps, delay-type electric blasting caps, and electric squibs in the presence of radio frequency (RF) radiation. The safe distances and currents apply only to caps which have been declared authorized under the provision of The Explosives Act of Canada. This part applies to radio transmitters, such as broadcasting, beyond-the-horizon, mobile communications and other similar transmitters, as well as to television and radar transmitters. It also includes industrial RF heaters, and equipment for geophysical surveys, particularly where aircraft are involved. This part does not apply to fireworks of flammable liquids, or to explosives other than electric blasting caps and squibs. It does not consider RF fields from lightning or electromagnetic fields from power lines.

MICROWAVE RADIATION HAZARDS

California State Department of Public Health
Bureau of Occupational Health

Type: Class C. California State Guide.

Intended Compliers: Users and manufacturers of microwave equipment.

Intended Benefitters: Users of microwave equipment and general public.

Limits and Specifications

The working tolerance levels for whole-body exposure have been established in terms of field intensity flux, in watts or milliwatts per square centimeter (W/cm^2 or mW/cm^2).

The Bell Telephone Laboratories have set up the following tolerance levels:

1. More than 0.01 W/cm^2 - potentially hazardous.
2. 0.001 to 0.01 W/cm^2 - safe for incidental or occasional exposure.
3. Less than 0.001 W/cm^2 - safe for indefinitely prolonged exposure or permament assignment.

General Guidance

A program of safety must include evaluation of the hazard in occupied or potentially occupied areas. For this, evaluation information is needed about (1) type of microwave installation, such as: frequency of wave, power level, gain, duty cycle, angle of rotation, and so forth; (2) calculated distances from the antenna to the boundary of potentially hazardous zones; (3) locations of working personnel and the general population with respect to the radiating antennas; (4) presence of highly reflective surfaces that may intensify beams in specific locations; and (5) accurate measurement of existing radiation intensity levels by reliable instruments in the hands of personnel well trained in the use of such equipment.

The guide includes suggestions for measuring microwaves.

The information obtained from surveys is evaluated in terms of biological effects of microwaves which are summarized in the following table.

Biological effects of microwaves

Frequency	Wavelength	Site of major tissue effects	Major biological effects
>10,000	<3	Skin	Skin surface acts as reflector or absorber with heating effects
10,000	3	Skin	Skin heating with sensation of warmth
10,000 to 3,300	3 to 10	Top layers of skin, lens of eye	Lens of eye particularly susceptible
10,000 to 1,000	3 to 30	Lens of eye	Critical wavelength band for eye cataracts
1,200 to 150	25 to 200	Internal body organs	Damage to internal organs from overheating
<150	Above 200		Body is transparent to waves above 200 cm

Protection from microwave radiation can often be accomplished by shielding in the form of area barriers or protective clothing. Radiation can be absorbed by certain materials, such as animal hair impregnated with a rubber and graphite mixture or reflected by wire mesh constructed according to exact mathematical calculation. The major requirements of an effective protection garment are: reduction of high-level fields external to the garment to safe levels inside the garment; protection against high-voltage gradients built up in the garment; and minimum restriction of visibility, mobility and dexterity.

Since absorption suits would be too cumbersone to wear, the most reasonable technique is to reflect the energy. A suit was designed and used that withstands severe mechanical and environmental tests; it allows complete freedom of movement without obstructing the wearer's visibility. It can be worn with safety in an electromagnetic field whose power density is 10,000 times more intensive than the present safe limit.

Since the eyes are particularly susceptible to damage, suitable eye protection should be used whenever a potential exposure exists. Devices, consisting of metallic covers perforated with minute holes, are available.

In the manufacture and testing of klystron tubes and other sources of microwaves, small beams may be released. It is essential, therefore, that potentially hazardous power densities, even of small areas, be recognized and rendered harmless.

In addition to the direct hazards from the microwaves themselves, one must consider the possibility of exposures to the byproduct emissions such as x rays, ultraviolet rays, and infrared rays from the klystron tubes; furthermore, the high voltages used for generation of microwaves present the possibility of injury by electric shock.

The Navy Department has rules relating to aircraft fueling in the presence of radar beams, and the National Fire Protection Association (NFPA) has set up a Standard for "Aircraft Fueling on the Ground" (Number 407) which has guidance procedures for fueling operations where radar beams are in use.

For rules of Navy Department see: Safety Precautions for Shore Activities, U.S. Navy Department, NAVSO P-2455, April 1965, Chapter 4, paragraph 0415-8; Chapter 15, paragraph 1543.

Safety Precautions Relating to Intense Radio-Frequency Radiation

The British Post Office (BPO)
25822 Wt. 2006-37290 K24 4/60
CP. LTD. 999/226
London.

Type: Class C. British Post Office recommendation.

Intended Compliers: Users and manufacturers of RF equipment.

Intended Benefitters: Users of equipment and general public.

Limits and Specifications

For frequencies between 30 and 30,000 MHz the recommendations are:

1. For continuous daily exposure - 10 mW/cm^2, and
2. In the case of pulse systems, the radiation is to be averaged over complete trains of pulses, including any intervals between pulse trains.

General Guidance

The report gives the maximum permissible exposure limits of 10 mW/cm^2 and the interpretation of these values for pulsed or rotating equipment. Details are given for protection of the general public from fixed, mobile, and industrial and scientific equipment. Protection consists of placarding, fencing areas, and preventing dangerous levels of radiated energy from reaching the public. Protection of operating and maintenance personnel entails shielding, protective clothing and fences. Details are given.

RF measuring devices are specified to have errors of -0, +2 db in the plane-wave power levels of 5 to 20 mW/cm^2. Other operating specifications for the measuring equipment are included.

Directions are given for action to be taken when exposures above the limits have occurred.

Exposure precautions:

Category	General public	Operating and maintenance personnel	Research, experiment and testing personnel
Protection	placards fenced areas directing beam	shields protective clothing placards	shields protective clothing placards
Measurement	Average over 1 second except for rotating antennas	Average over 10 seconds for close-field rotating devices	Average over 10 seconds for close-field rotating devices
Special	Applies to mobile, fixed statings, and scientific, medical and industrial equipment	Certain less vulnerable parts of the body may momentarily enter high field areas (hands, feet, and so forth)	Should have health safety officer make periodic safety checks

ENVIRONMENTAL HEALTH SERIES

RADIOLOGICAL HEALTH

The following technical reports issued by the Bureau of Radiological Health are available through the Office of Public Information and Education, Bureau of Radiological Health, Public Health Service, U.S. Department of Health, Education, and Welfare, Rockville, Md. 20852.

PHS Pub. No.	Title
999-R-1	Factors Influencing Strontium-90 in Milk from Brainerd, Minn. Milkshed
999-R-2	Rapid Methods for Estimating Fission Product Concentrations in Milk
999-R-3	Studies of the Fate of Certain Radionuclides in Estuarine and Other Aquatic Environments
999-R-4	Mathematical Programming Models for Selection of Diets to Minimize Weighted Radionuclide Intake
999-R-5	Radionuclide Analysis of Gamma-Ray Spectra by Stepwise Multiple Regression
999-R-6	Farming Practices and Concentrations of Fission Products in Milk
999-RH-7	An Environmental Surveillance Laboratory for Radionuclide Analyses
999-RH-8	X-Ray Equipment Survey in Polk County, Florida - September 1961-August 1963
999-RH-9	An Emanation System for Determining Small Quantities of Radium-226
999-RH-10	Procedures for Determination of Stable Elements and Radionuclides in Environmental Samples (superseded by 999-RH-27)
999-RH-11	Radiochemical Determination of Uranium in Environmental Media by Electrodeposition
999-RH-12	Radioactive Decay Correction Factors (out of print)
999-RH-13	Behavior of Certain Radionuclides Released into Fresh-Water Environments Annual Report 1959-1960
999-RH-14	Iodine-131 in Children's Thyroids from Environmental Exposure
999-RH-15	Quality Control of Radioactivity - Counting Systems
999-RH-16	Medical Uses of Radium and Radium Substitutes
999-RH-17	Radionuclide Analysis of Large Numbers of Food and Water Samples
999-RH-18	Mortality of New England Dentists 1921-1960
999-RH-19	Soil and Sediment Analysis: Preparation of Samples for Environmental Radiation Surveillance
999-RH-20	Standards of Performance for Film Badge Services
999-RH-21	A Computer Program for the Analysis of Gamma-Ray Spectra by the Method of Least Squares
999-RH-22	Scientific Information Retrieval System for Research Grants
999-RH-23	Routine Surveillance of Radioactivity Around Nuclear Facilities
999-RH-24	Distribution of Cobalt 60, Zinc 65, Strontium 85, and Cesium 137 in a Freshwater Pond
999-RH-25	Radionuclide Standardization - A Bibliography
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